

The soul and the pneuma in the function of the nervous system after Galen

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Summary

Galen's teaching on anatomy and physiology was generally accepted in the Middle Ages and this applies to the part he thought was played by the pneuma in the functions of the body. In this essay I have outlined the advances made after Galen in the study of the nervous system leading eventually to a time when the soul and the pneuma were no longer thought necessary for the proper functioning of the brain and nerves.

Introduction

Herophilus living in Alexandria around 300 BC identified the nerves as structures connected to the brain and concerned with sensation and movement; Galen (AD 131-201) confirmed his findings. Galen, like the Alexandrian physician Erasistratus (fl. 260 BC), incorporated the pneuma in his physiology and he said that air drawn in through the trachea was changed in the lung tissues to become vital pneuma. The vital pneuma mixed with blood travelled in the arteries to the base of the brain where it was transformed into psychic pneuma. The psychic pneuma or spiritus animalis was responsible for the proper functioning of the brain and nerves, but it must be distinguished from the soul¹. The soul, according to Galen, was related to the humoral composition of the brain and he could not therefore agree with Plato that man had an immortal soul independent of the body². For Galen, therefore, the soul was intimately connected with brain tissue which he thought communicated with the nerves by means of the psychic pneuma.

Mental faculties located in the cerebral ventricles

Religion dominated the thought of Europe after the conversion of the Emperor Constantine to Christianity in the fourth century. The views of bishops, even in physiological matters, became influential. Thus a Christian writer, Nemesius, Bishop of Emesa in Syria in the fourth century thought man had an incorporeal soul which permeated the whole of the body. Nevertheless, the mental faculties such as sensory activity, reason and memory resided in the brain, but in the ventricles rather than the cerebral substance as Galen had maintained³.

Aristotle's influence after the twelfth century

In the twelfth century translations from Arabic into Latin revealed ancient Greek philosophy and science to western Europe. The writings of Aristotle became available, but were not at first acceptable to the Church as some of his ideas especially as interpreted by the Islamic physician and philosopher Averroes

seemed incompatible with the Christian faith. The work of St Thomas Aquinas (1225-1274) brought about a reconciliation between Aristotle's philosophy and Christian doctrine. Galen had produced good evidence that the brain was the centre controlling sensory and motor activity and not the heart as claimed by Aristotle, but the acceptance of the ideas of this philosopher revived the controversy of brain versus heart as the 'ruling part'. Although the heart was now considered by some physicians to be the seat of the soul it was usually postulated that the brain had a part to play, but it was only after it received 'spirits' from the heart that it could participate in sensory and motor activity⁴ (pp 104-7).

Criticism of the doctrines of Aristotle and Galen

The authority of Galen in medical matters was seldom challenged in the Middle Ages. One of the first to criticize his doctrines was Paracelsus (1493-1541). He was opposed to Galen's humoral concept of disease, and he favoured a new start in medicine, namely, a chemical approach. Although Paracelsus was critical of Aristotle as well as Galen he nevertheless regarded the heart as the seat of the soul, but thought spirit passed from the heart to the brain which was the centre of reason⁵. Andreas Vesalius (1514-1564), the professor of anatomy at Padua, was unable to confirm a number of Galen's anatomical findings, but he was certainly in firm agreement with his conclusion that the brain was the centre of sensory and motor activity and moreover he rejected the idea that the ventricles were the site of mental faculties such as reason⁴ (pp 107-12). Later William Harvey (1578-1657) gave mechanistic explanations of his observations and of the results of his experiments on the heart and blood vessels and in this way demonstrated the circulation of the blood. Moreover he stated clearly that he was unable to find natural, vital or animal spirits (spiritus animalis or psychic pneuma) in his dissections and that discussion of the part they played in the functions of the body was merely an attempt to avoid admission of ignorance⁶. In spite of this severe criticism regarding the existence of 'spirits' speculation about their part in brain function continued; thus in 1690 the philosopher and physician John Locke in his *Essay Concerning Human Understanding* associates thinking with motions in the animal spirits⁷.

The mechanistic approach to physiology

René Descartes (1596-1650) put forward mechanistic explanations of the functions of the body, but many of them were not supported by actual observations. Nevertheless, his approach to physiology was very influential for it encouraged observation and also experiment along mechanical lines. His description

of brain, nerve and muscle function is therefore of interest. Although Harvey doubted the existence of spirits Descartes employed the animal spirits of Galen as a basis of nerve and muscle function, but their action was purely mechanical. He thought man had a rational soul independent of the body, but no soul of any kind was present in other animals which in his opinion functioned like automata. He tried to show how it was possible for the bodies of animals to function without the guidance of a soul. He referred to the finest particles in the blood which on reaching the brain passed to the pineal gland where they became the animal spirits.

Animal spirits, which he likened to a wind, were transmitted from the pineal gland to pores in the lining of the ventricles of the brain and thence to nerves and muscles. The nerves consisted of fine tubes containing animal spirits, but in addition of filaments connecting sense organs to the inner aspects of the ventricles. Stimulation of a sense organ brought about pulling on these filaments which resulted in opening of the pores in the walls of the ventricles and thus permitting transmission of the spirits to the muscles. By this mechanism there is an automatic response which we would term a reflex. Descartes illustrates the process by a flame impinging on a foot so that its withdrawal occurs together with movement of the eyes to see what is happening and of the hand to remove the unwanted stimulus. The brain, however, plays an essential part in the Cartesian reflex. Actual movement is brought about by the animal spirits causing inflation of muscles and their shortening as originally described by Erasistratus. The distribution of spirits flowing from the pineal corresponds with pores which have opened as a result of sensory stimulation and consequently changes in the pineal mirror the sensations. As noted earlier Descartes postulates for man, though not for other animals, a rational soul independent of the body. He thought interaction between soul and body took place in the pineal gland and it was there that conscious appreciation of sensations occurred and voluntary movements were initiated⁸.

The mechanism of muscle shortening

The notion that shortening of a muscle resulted from its inflation by a fluid was questioned by Francis Glisson of Cambridge. He described an experiment in which a man placed his arm in a glass tube sealed at the shoulder end with clay and having at its distal end an upright tube. The main tube was filled with water some of it extending into the upright portion and when the man contracted his muscles the water in the upright tube fell to a lower level thus providing evidence against the inflation of muscles by spirits⁹ (p 218). Jan Swammerdam (1637-1680) in Amsterdam carried out experiments on frog's muscle enclosed in a glass tube with a fine capillary tube containing a drop of water attached at its upper end. The nerve to the muscle passed through a hole in the larger tube and this opening was sealed with isinglass and starch. With this apparatus he demonstrated that the volume of skeletal muscle does not change appreciably during contraction. His results, which were not published until 1738, provided further evidence against the theory that muscle shortening resulted from its inflation with animal spirits⁹ (p 212).

Development of the concept of reflex action

As noted above Descartes described an automatic response to a stimulus in man that could be regarded as an example of reflex action. Thomas Willis (1621-1675), who made a number of contributions to knowledge of cerebral anatomy, was influenced by Descartes's ideas. He described an automatic response to pain by rubbing the affected part, an action which can occur in sleep and it has been likened to Sherrington's scratch reflex. Willis actually uses the term 'reflected' in relation to animal spirits proceeding from a sensory organ to the brain and thence returning to the periphery to cause muscle action. The reflex arc of Willis, like that of Descartes, was still centred on the brain¹⁰. Galen's opinion that the spinal cord is a large bundle of nerves without any independent activity still received support and the part it played in reflex action had yet to be discovered¹¹.

Vitalist views

In sharp contrast to the mechanistic views of Descartes were those of the German physician and chemist Georg Stahl (1660-1734) who thought it was necessary to introduce an immaterial agent, the anima or soul, if living processes were to be understood. Vitalist views sometimes provided a stimulus leading to important investigations in physiology¹². Thus Thomas Whytt of Edinburgh (1714-1766) thought a sentient principle or soul was essential for living processes and that it linked sensibility and muscle irritability in the brain or spinal cord; such connections could be regarded as equivalent to a reflex centre in the nervous system. He confirmed the experiment of Stephen Hales (1677-1761) who had found that the feet of a decapitated frog still responded to skin stimuli, but that this response ceased when the spinal cord was destroyed¹³. Experiments by Julien Legallois (1770-1814), also a vitalist, showed that response to stimulation of a relevant area of skin occurred when only a small portion of the spinal cord was intact¹⁴ (p 295-6). Galen's doctrine that the spinal cord was merely a bundle of nerves could no longer be maintained.

The function of the anterior and posterior roots of the spinal cord

Although Georg Prochaska of Bohemia (1749-1820) considered the nervous system to be the seat of a rational soul he rejected the notion of Stahl that every movement is directly regulated by the soul¹⁵. He referred to impressions transmitted along sensory nerves to their origin where they are 'reflected' and pass into a motor nerve and thence to a muscle, but the function of the anterior and posterior roots had yet to be defined. In 1811 the surgeon Sir Charles Bell of Edinburgh concluded as a result of animal experiment that the function of the anterior roots was motor and in 1822 François Magendie in Paris demonstrated by similar experiments not only the motor function of the anterior roots, but also that the posterior roots were concerned with sensation¹⁴ (pp 297-8, 300-1).

Reflex action firmly established

Marshall Hall (1790-1857) first used the terms 'reflex' and 'reflex arc'. In his paper entitled *On the Reflex Function of the Medulla Oblongata and Medulla Spinalis* published in 1833 he gave a detailed

description of the reflex arc with its centre in the spinal cord. He pointed out that stimulation of an afferent nerve could do more than produce a segmental response for efferent nerves at a higher level could be affected¹⁴ (pp 347-51). The principle of reflex action together with the results of other investigations of nerve function along mechanistic lines gradually made the concept of animal spirits obsolete. In the last two paragraphs the contributions of a number of physiologists to the study of the physical and chemical properties of nerves is outlined and the last reference concerns relevant excerpts from their writings.

Animal electricity

Although Glisson and Swammerdam had shown that shortening of muscle was not caused by distension with fluid, the possibility that flow of nerve juices was responsible for nerve action was still entertained in the eighteenth century. However, Alexander Monro primus of Edinburgh writing in 1746 found no evidence of flow of nerve juice; thus there was no swelling of a nerve proximal to a ligature. The notion that electrical transmission might be responsible for nerve action was often discussed. Luigi Galvani (1737-1798) carried out experiments on the nerves and muscles of frogs and he thought they demonstrated the presence of animal electricity, but Alessandro Volta (1745-1827) showed that this conclusion was incorrect and that the source of electricity was contact of dissimilar metals. Later, however, it was shown that when the cut end of the spinal cord of a frog touched the leg muscles a contraction resulted; in this experiment no metals were involved and the contraction was due to the current of injury. In 1842 Carlo Matteucci using a galvanometer confirmed the findings of Galvani regarding the current of injury.

The current of action investigated in Germany

The work of Matteucci and of Emil Du Bois-Reymond (1818-1896) led to the recognition of the current of action in nerve and muscle. Du Bois-Reymond suggested that the nerve principle, by which he meant the nerve impulse, was in its transmission the same as electricity, but arguments were put forward against this idea and the measurement of the velocity of the nerve impulse by H von Helmholtz in 1850 made it untenable. He found the velocity to be in the region of 26 m/s which was very much slower than the flow of electricity in a conductor. Ludimar Herman in 1867 described the current of action as electro-negativity proceeding from the point of stimulation and self-propagated along nerve and muscle. He insisted that older theories which tried to explain

nerve transmission by nerve juices should be discarded. Julius Bernstein (1839-1917) studied the propagation of the electronegativity from a point of stimulation in a nerve and found that its velocity was the same as that of the nerve impulse. He put forward an explanation of the current of action in terms of movements of ions across a semipermeable membrane and this pointed the way to modern ideas on the nature of the nerve impulse¹⁴ (pp 163, 175, 183-7, 193, 207, 210-13, 214-16).

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